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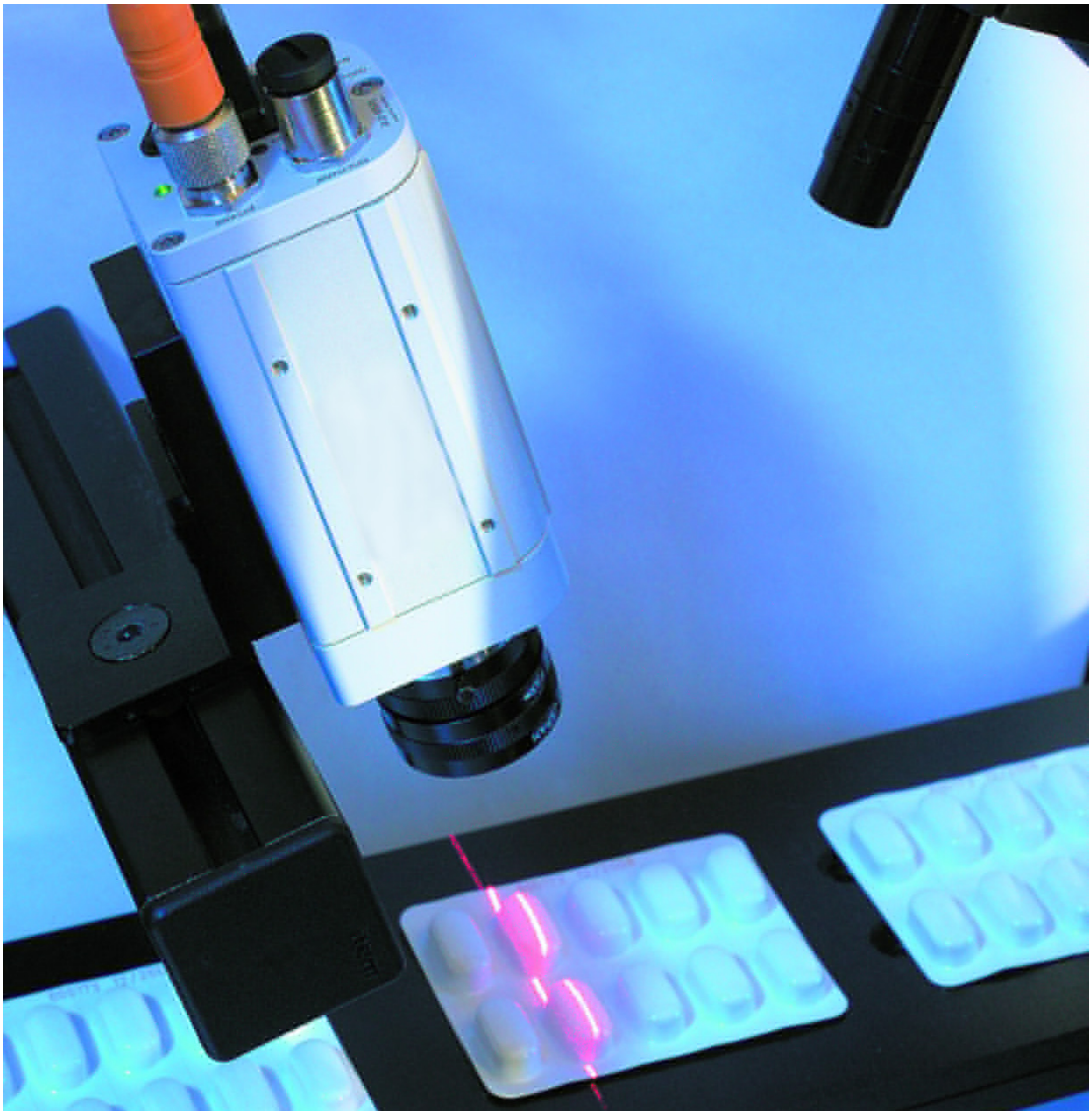
Machine Vision: The key considerations for successful visual inspection

There is no such a thing as an "off-the-shelf" vision system. Just like a drive- or a PLC-based control system, each one is unique and each one is engineered and thought about. The customers' objectives may be similar to each other as to what they want to achieve with visual inspection. This is why some people think vision is a simple, one-fits-all solution when, in fact, it is not.

APPLICATIONS

Machine vision utilises high-quality imaging methods and has a broad scope of applications across a wide variety of industries such as Food and Beverage, Consumer Packaged Goods, Electronics, Automotive, Pharmaceutical and Solar to name a few. More recently machine vision has moved outside, quite literally, into a variety of new areas such as number plate recognition and traffic control.

For most processes a common objective of utilising vision is to reduce production costs. By automatically detecting defects earlier in the production process and rejecting these before further wasted processes are carried out. Such applications are typical in the automotive industry. Employing vision technologies may also release valuable labour certain repetitive inspection and so improve productivity, process and quality and efficiency metrics - a well-designed vision system will deliver a 100% product inspection rate and significantly improve manual type inspection achievements.



VISION SYSTEM ESSENTIALS

There are two critical elements in any successful vision system: lighting and the selection of vision technology used. The correct determination of these two system components is crucial and is helped enormously by, at the project outset, producing a good specification document and performing preliminary trials with real samples of the vision system's target products. As with any engineering project, there is a trade-off between hardware and engineering costs. One will either pay less for hardware and more on engineering time or visa versa. It is a matter of choice and is influenced by the clients' ownership philosophies.

We herein consider some options to be considered regarding the two critical elements.

LIGHTING

Correct lighting is critical to a successful machine vision installation. A substandard lighting arrangement will prevent the system from working to its optimum potential. It may result in additional engineering time needed, reduced reliability or perhaps increased image processing times to achieve a working system.

The engineer will design the lighting system according to what is being inspected and rarely are two systems alike. The design process involves the consideration of a number of key questions:

1. **Colour** – Does the inspection task require the use of colour or monochrome vision technology?

2. **Surface properties?** – Is the subject component's surface fully or partially reflective or matt?

3. **Geometry** - What shape is the component?

4. **Features of interest** – Which part of the object will be inspected and can they be reliably discerned?

5. **Service Life –** How long must the light last before a service? E.g. LED vs. fluorescent tube light sources have significantly different projected life spans.

Lighting Tasks

The basic objective of the lighting arrangement in all vision systems is to achieve good contrast of the camera's image and so optimise the systems operational performance.

Good lighting design is essential. It is important to recognise that no two lighting applications are the same and that there is a vast array of lighting types with particular models often being designed to suit specific material types. So holding lighting design experience has a distinct advantage.

Below we consider two fundamental lighting modes.

Backlighting vs. Front Lighting Methods

Back lighting involves the positioning of light source behind the inspected object with the inspection camera mounted in front and in-line with the inspected object. This method will highlight and geometric faults in the object by comparing the measured shape against a known "good sample" shape (*see figure 1 below*).

With ***Front lighting*** techniques the inspected object is illuminated from the same side as the inspection camera. A method employed applications where finer detail inspection is required.

A vision system's design, its cost and its successful operation rely upon choosing the correct lighting technique for the specific application. This is the reason we visit the customers site in order to determine our solution with confidence. Seeing a sample of the product on site also gives us an insight to the production environment and the ambient lighting conditions, also a critical factor in system configuration.

Figure 1. Backlighting creates good contrast for shape inspection

LENSES AND SENSORS

All cameras collect light reflected from the surface of an object via a lens. The light is focused on an electronic photo sensor from where it is digitised for processing: -

The lens therefore is another critical system component with design options to be made considered.

Lens Mount – How the lens will be attached to the camera. There are a number of available options. Selecting the wrong lens for the wrong camera mount may result in not only mechanical issues but also the ability to obtain a focused image or any image at all.

F-Stop (Aperture) – defines how much light can pass through the lens, a small aperture gives a greater depth of field or focus (the range of distances that an object appears in focus) than a large aperture, e.g. to perform a product inspection on pots of different heights without continually changing the camera configuration reduce the aperture of the lens and increase the amount of light from external light sources.

Lens quality (Resolution and Distortion) – a lens with a poor resolution may mean that you are unable to fully utilise your chosen camera features. Also a lens that seriously distorts the captured image may impact on the ability to accurately process that image for the application i.e. for measurement applications. Example lens manufactures include Linos, Schneider, Pentax and Tamron.

Sensor size – the lens must be designed to work with the size of the sensor of the selected camera or work with a larger sensor than required. Selecting a lens for a smaller sensor size than is actually on the camera will significantly increase any distortion of the image around its edges.

Lens types include Standard Resolution (the most commonly used), High Resolution (for measurement applications), Macro (designed for small fields of view i.e. microscope type applications), Large Format/F-Mount (typically used for line scan applications i.e. web inspection) and Telecentric (used in specialist measurement applications i.e. wire gauge measurement).

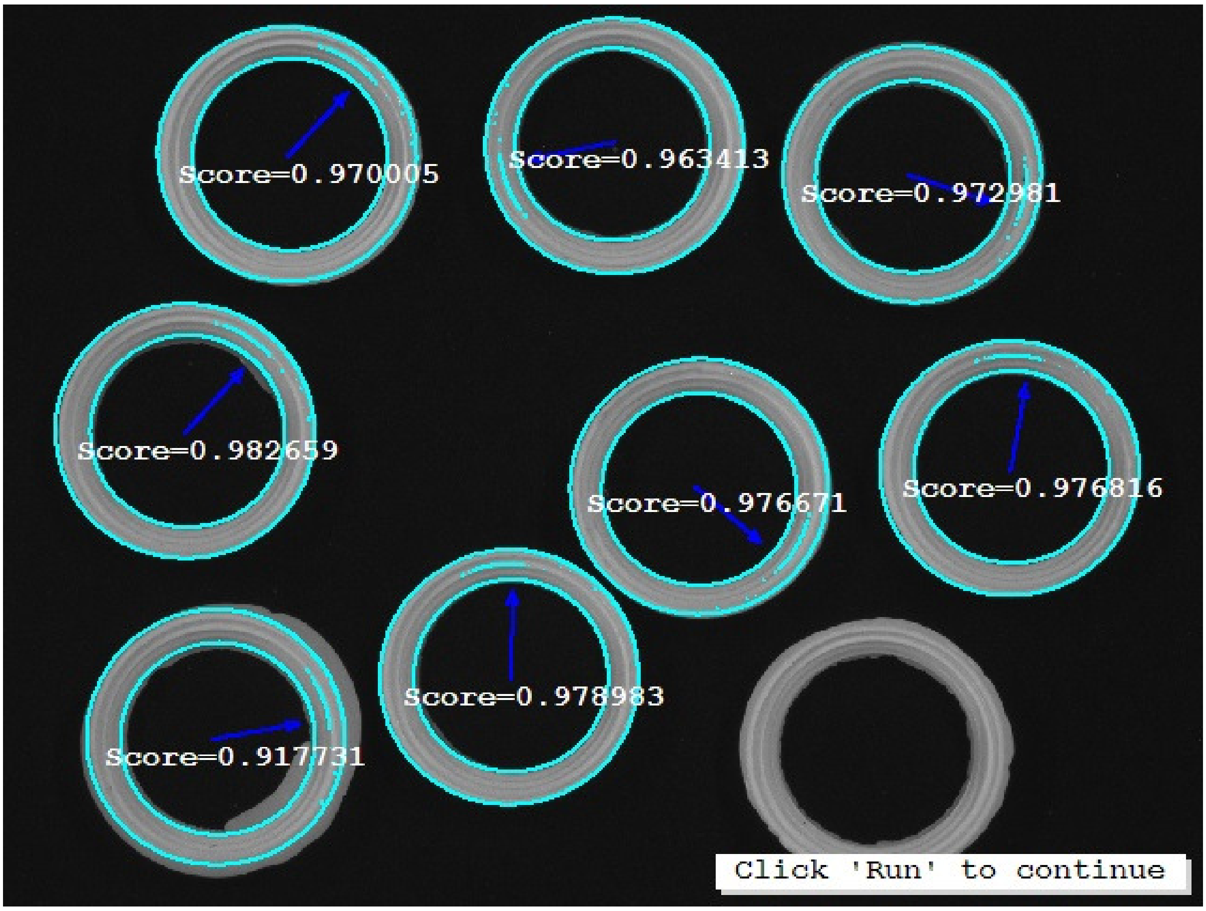


Figure 2. Example of using standard resolution lenses to detect defect parts

VISION SYSTEM TYPES

There are three main types of machine vision system technology & sophistication:

1. **Simple vision sensors** - Provide a very cost effective solution for basic vision applications where only one inspection type is required, e.g. to determine a part being present or absent

2. **Smart Cameras** - These combine camera functionality with functional inputs and outputs are custom-programmable in one compact package. This mid-range equipment has the advantage of lower costs and are ideal where only one inspection view is required and where no HMI or user control is required. They are also deployed in environments where it is not possible to use PC based

systems. Costs can increase however if multiple cameras are required for an application.

3. **PC based vision systems** - Provide the greatest flexibility in terms of vision software and hardware choices and will provide powerful tools to process the images captured from cameras supporting a large array of comms standards.

IMAGING

2D or not 2D? That is the question.

Many machine vision applications use 2D image technology and obtain satisfactory results.

However, in some cases, the use of a 2D image may not yield the best results e.g. in robotic bin picking applications, where the contrast of product against its background is poor or checking that the correct number of chocolates are in a box. In these instances the use of 3D may be necessary. The most common 3D systems use a laser to generate a set of profiles of the inspected object as it passes beneath the camera.

Other 3D systems include "Stereoscopic Vision", where 2 cameras are used to produce a combined image (similar to the way human eyesight works) or "Time of Flight", where the time taken for an infrared beam to reflect back to the camera, is used to determine distance.

3D imaging is typically used in applications such as Robotic bin picking, Optical Character Recognition (OCR) on tyre walls or checking for missing tablets within blister packs for example.

Figure 3. 2D Imaging used to verify correct labelling and 'best before' dates

INTEGRATION WITH CONTROL SYSTEMS

Vision systems can either run independently from the host control system e.g. in simple applications when controlling a simple reject mechanism via Digital I/O, or can be integrated with a host machine's PLC or SCADA system. It is common for modern Vision Sensor or Smart Camera systems to support a variety of industrial communications protocols i.e. PROFINET, Serial, Ethernet/IP, MODBUS, Digital I/O etc.

For PC based systems, similar functionality can be provided through the use of widely available PCI/PCI-e cards.

These communications protocols permit full integration to SCADA and HMI equipment, allowing the associated advantages of pre-determined recipe selection of specific inspection criteria, process tracking and data collection for quality and productivity purposes.

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